STEP-NC CODE GENERATOR FOR DRILLING OPERATION USING GEN-M

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In loving memory of my beloved father Zamri Tan Abdullah

Special dedication to husband, sons, mom and siblings:

Saiful Zaree Bin Johar

Ahmad Umar Bin Saiful Zaree

Muhammad Ammar Bin Saiful Zaree

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ABSTRACT

STEP-NC used to transfer machining data between STEP-NC compliant Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) and Computer Numerical Controller (CNC). It has gain worldwide consent when International Standard of Organization (ISO) has established a new data model for ISO 14649. By implementing STEP-NC, profitable and intelligent manufacturing are very convincing. It overcomes G & M code weakness which has thousand lines of codes but none of them define the machining process. In order to create a complete chain of STEP-NC system to be a new way of producing product in manufacturing environment, a new CNC machine and CAM software that compliant to STEP-NC has to be developed. This research is a software development that name as GEN-M using Visual Basic.Net 2010. The success of GEN-M development contributed a new application to serve new manufacturing environment in generating STEP-NC code for machining. Although there are many researches produces new application software, GEN-M can be a variety of CAM software that compliant to STEP-NC. More over GEN-M have few attractive functions such as redirecting users to a website for seeking about STEP-NC information; email the generated STEP-NC program to other parties and more. GEN-M is successfully developed where the verification process which is the generated code by GEN-M is compared to ISO 14649 Part 11 gave less number of different with reasonable cause and more similarities for related entities. Therefore the software is capable to generate code for drilling referring to selected case study from Annex F (Example 1) in ISO 14649 Part 11. This research can be a stepping stone to the next level of research.

ABSTRAK

STEP-NC berfungsi untuk menghantar data pemesinan antara *Computer Aided Design* (CAD), *Computer Aided Manufacturing* (CAM) dan *Computer Numerical Controller* (CNC) yang mematuhi STEP-NC. Ia mendapat perhatian dunia setelah *International Standard of Organization* (ISO) mengeluarkan data model untuk ISO 14649. Dengan melaksanakan STEP-NC, pembuatan pintar dan memberi keuntungan kepada pembuatan lebih meyakinkan. Ia mengatasi kelemahan kod G & M yang mempunyai beribu baris kod tetapi tiada satu diantaranya mendefinisikan proses pemesinan. Untuk menghasilkan satu kitaran lengkap bagi sistem STEP-NC, mesin CNC dan perisian CAM baru yang mematuhi STEP-NC harus dihasilkan. Kajian ini ialah pembangunan perisian yang dinamakan sebagai GEN-M menggunakan Visual Basic.NET 2010. Kejayaan pembangunan GEN-M menyumbang satu aplikasi baru untuk bekerja pada persekitaran pembuatan yang baru bagi menjana kod STEP-NC kepada pemesinan. Walaupun terdapat banyak kajian bagi menghasilkan aplikasi perisian yang baru, GEN-M boleh menjadi satu variasi untuk perisian CAM yang mematuhi STEP-NC. Malah, GEN-M mempunyai beberapa fungsi yang lebih menarik seperti mengubah hala pengguna daripada GEN-M ke laman sesawang untuk mencari maklumat berkaitan STEP-NC; menghantar emel kepada pihak lain dan banyak lagi. GEN-M dianggap berjaya dibangunkan apabila proses verifikasi dimana, kod yang dijana oleh GEN-M dibandingkan dengan *ISO 14649 Part 11* memberikan jumlah perbezaan yang sedikit dengan sebab yang munasabah dan lebih banyak kesamaan untuk *entities* yang berkaitan. Oleh itu, GEN-M telah berjaya dihasilkan di mana ia berupaya untuk menjana kod STEP-NC bagi proses ‘drilling’ merujuk kepada kajian kes yang dipilih iaitu *Annex F (Example 1) in ISO 14649 Part 11*. Kajian ini boleh menjadi batu loncatan untuk kajian pada tahap yang seterusnya. .

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LIST OF SYMBOLS AND ABBREVIATIONS

ANSI	-	American National Standards Institute
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CAPP	-	Computer Aided Process Planning
CNC	-	Computer Numerical control
DFX	-	Drawing Exchange Format
DWG	-	Drawing
EDM	-	Electric Discharge Machining
EIA	-	Electronic Industries Alliance
F	-	Feed rate
G	-	Preparatory functions
GUI	-	Graphical User Interface
IGES	-	Initial Graphics Exchange Specification
ISO	-	International Organization for Standardization
M	-	Miscellaneous
MDI	-	Multiple Document Interface
MIT	-	Massachusetts Institute of Technology,
NC	-	Numerical Control
PDM	-	Product Data Management
R	-	Radius
S	-	Spindle speed
SQL	-	Structured Query Language
STEP	-	Standard for the Exchange of Product model data
T	-	Tool
VB	-	Visual Basic
XML	-	Extensible Markup Language

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CHAPTER 1

INTRODUCTION

1.1 Research background

The revolution of Computer Numerical Control (CNC) started at the end of Second World War. It was first discovered by John Parson in 1949 (Seames, 2001). Early CNC machine received command from punch card and tape and later computer was introduced to aid the programming (Seames, 2001). CNC may be unfamiliar term to some people but without notice, it has touched a lot of aspect in the daily life where many types of equipment are machined by CNC such as medical equipments, cutleries, war weapons and transportation. In mass production, CNC seems to have met the requirement in giving profit to manufacturers. Products are easily, faster, and repetitively produced using automation system (Smid, 2003).

Current manufacturing cycle involve processes to machine a workpiece started by designing the part with Computer Aided Design (CAD). Then it transferred to Computer Aided Manufacturing (CAM) with variety of file format such as DFX/DWG, IGES, ACIS, Parasolid and native CAD. CAM will develop the machining process using postprocessor which convert the process to G & M code. In mass production, this code seems to be not practical to the manufacturers because thousand lines of G & M codes become a drawback and seem to be a bottleneck to CNC system. None of the line describes the overall process of the machining

(Thilmany, 2007) and the program is limited with information only on machine movement and some special features such as coolant. Data exchange with variety of file format is also sticky, when some file is broken and missing due to CNC vendor specific features. Therefore, it always needs new postprocessor every time to start new work piece machining. Due to the limitation of this code, STEP-NC was developed to replace ISO 6983 (Callen, 2002).

Modern manufacturing industries demand CNC a higher level input language than outdated G & M, and less proprietary vendor dependencies. In order to generate G & M programs for different CNCs, CAM tools need to know not only the particular brand and model of a CNC, but also need to have a detail description of the machine tool and their peripherals such as cutting tools and other auxiliary components (Xu et al., 2006).

This information is being handled by a special unit within a CAM tool called postprocessor. The ability to generate an Numerical Control (NC) tool path is now commonplace from CAD/CAM systems, but the technology used to program NC machines is still based on 1950's standards which is known as G & M code (Smid, 2003).

It is almost fifty years G & M code used in manufacturing industry to machine part (Suh et al., 2008b). Along the way, a lot of enhancement constructed to enhance the way data transferred between CAD/CAM and CNC so it is easier, faster and agile around the world. In fact, the data is adaptable and able to be used at any brand of CNC machine with ignorant to the vendor specific function. This way, the G & M code does not need to recode again. There is no doubt CNC machine is becoming more advance to machine part but the problem of limited information in G & M code and limited data transfer is still there.

ISO 14649 which also known as STEP-NC is still in improvement phase with various research around the world where there are striving to create data transfer medium (software) with a lot more features (International Organization for Standardization, 2003). Due to the low STEP-NC research and acceptance in Malaysia, research is at low level and a lot of thing is possible to explore. As a suggestion to boost the research activities, a group of expert should form a committee to share knowledge, experience and expertise.

The development of the ISO 14649 data model gains significant impetus on the way to becoming an International Standard, the issues of how to create

CAD/CAM system that are the ISO 14649 compliance and their levels of compliant will depend on the industrial use and software vendors acceptance of the standard (Smid, 2003).

Currently, research on STEP-NC is getting improved and when it is come to the implementation it is believed to be the remedy of G & M code's drawbacks. STEP-NC will affect the manufacturer and production that uses CNC's machine with G & M code program where the limitations of G & M codes make data transfer not agile and sharable with the CNC's machine commonly is vendor specific design. From 1996 where ISO 14649 has been established until today, STEP-NC had catch worldwide concern and many researchers had take an opportunity to explore the STEP-NC, which they believe to be the remedy of G & M codes (Ibrahim, 2010; Minhat et al., 2009; Suh et al., 2002; Yusof et al., 2009).

After many years of effort, adaptation of STEP-NC has not started yet. CAM vendors have to add system interface that write STEP-NC data while CNC machine makers have to add interface to read data (Thilmany, 2007). Moreover, without necessary demand vendors are hesitant to invest. CAD/CAM/CNC vendors make their system specific and special. They are unwilling to reveal their algorithms. However, to put STEP-NC becomes reality full collaboration between CAD/CAM/CNC vendors has to be developed. The research questions that describe the goal of this study are listed as following:

i. What is needed to understand the fundamental of STEP-NC?
ii. How to create software to generate STEP-NC codes?
iii. How to verify the generated STEP-NC program by developed software?

1.2 Research importance and impact

This research is important in order to bring a new machining environment in manufacturing industry especially in Malaysia. As STEP-NC can bring ease and agile data transfer, it is an opportunity to develop a system that may replace the old system thus it makes variety in manufacturing industry.

Other significant of this research is to promote the advantages of STEP-NC. This will open an opportunity to hold cooperation between researcher in universities, manufacturing industries, users, software developers and CNC vendors. Consequently, this research brings understanding to ISO 14649 fundamental and concept behind it as the standard is the brain to the key in developing software to generate STEP-NC code. This research is also to bring understand to ISO 14649 fundamental and concept behind it, as the standard is the brain to the key in developing software to generate STEP-NC code.

In the future, STEP-NC promising great profits to current manufacturing environment which it do not have to depend on CNC machine special function that has a postprocessor, where STEP-NC Controller is more to be more open, intelligent and interoperable (Xu et al., 2006). In this way, G & M code is no needed to be generated again and again due to many kind of CNC controller brand. Data transfer also can be done in anytime at anywhere. STEP-NC does not have to repeat the process cycle of machining again. Correction of machining data can be done directly in shop floor stage when STEP-NC controller is success to develop. Hereafter, with one click on the internet, data can be shared all over the world. STEP-NC controller not only can machine part due to the machine movement but it will understand the overall machining process including geometry and its machine technology.

1.3 Research objectives

The objectives of this research are:

i. To develop a software that capable to generate STEP-NC program for drilling in case study.

ii. To verify the generated program from the developed software with ISO 14649.

1.4 Research scope and limitation

The scope and limitation of this research will include as following:

i. The software is built to generate the STEP-NC code for drilling.

ii. This software is declared as non-commercialized application.

iii. The development of software is built using Visual Basic.Net 2010.

iv. The verification is a comparison of the generated STEP-NC program by GEN-M with the existed STEP-NC program in Annex F (Example 1) in ISO 14649 Part 11 for drilling.

1.5 Thesis organization

This thesis is organized into five (5) chapters. Brief descriptions of each chapter are as following:

Chapter 1 describes the purpose of this thesis which encompasses the background and problem statements, the importance and impact of research, objectives, scope, and limitation in this thesis. Basically it visualizes what the research is about.

Chapter 2 is focus on the deep explanation of research background that tells the revolution of CNC usage in manufacturing industry. A summary of history background on discovering of CNC will picture the significant of CNC usage in daily life. This chapter also comprises the theory and basic fundamental of STEP-NC. Other researches regarding STEP-NC were reviewed and self point of view is inserted. It also includes with the analysis of NC and STEP-NC program and it result. From the literature review, a specific goal and direction of this research is determined. It provides an understanding on the fundamental knowledge regarding STEP-NC and how the research has been done.

Chapter 3 presents the methodology used in this research. It mainly contains how the research was conducted. The chapter contains of the research procedure of GEN-M development, selected case study, instrument and verification procedure.

Chapter 4 shows the implementation of GEN-M and lastly is chapter 5 that recaps the research work and the contribution from this research. Lastly the suggestions to extend the research work and conclusion were made from what have been done.

1.6 Summary

This chapter gives basic overview of fundamental ideas on the research is about. It has outlined the objectives of the research, scope and limitations, and problem statements.

The following chapter is the anecdote of the research background that becomes a motivation to conduct this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review chapter contains the review of researches that has been done in the past ten years. It also describes the revolution of machining from conventional skills and machinery to modern CNC. A brief description on STEP-NC is also included to picture how it was discovered.

A comparative study between NC and STEP-NC program is also included. The comparative study contains of NC and STEP-NC program analysis and the result of analysis. This research is also added with some interviews to gain information and suggestion regarding STEP-NC that might help this research. The interview work is included in Appendix A.

Critical review and author's opinion of the review are also included. Previous researches that have been focused to set the direction of this study are on fundamental content of STEP-NC. From this literature review, points that have been succinct are the revolution or development on STEP-NC around the world, the expansion of STEP-NC in Malaysia, and the programming language that has been used to develop software to generate the STEP-NC code. Besides that, research that has been patented was also been covered and explained. Therewith, this part will picture why this research is needed.

2.2 Manufacturing cycle

Basically, in manufacturing process, it started from generating ideas and then the idea will be depicted into a sketch drawing. Nowadays, CAD is used to visualize the idea. CAD assist engineer to design part from simple line to 3D solid model. After designing with CAD, the drawing will be sent to CAM to generate machining tool paths based on user instruction (Kalpakjian et al., 2006). CAM assembles a series of these commands into machining instruction and converts all of it to G & M code that the machine controller can understand with a postprocessor. Postprocessor is a translator that allows the CAM software to understand the way CNC system work (Smid, 2003). Figure 2.1 depict the flow of machining process using CAD until part is machined using CNC system.

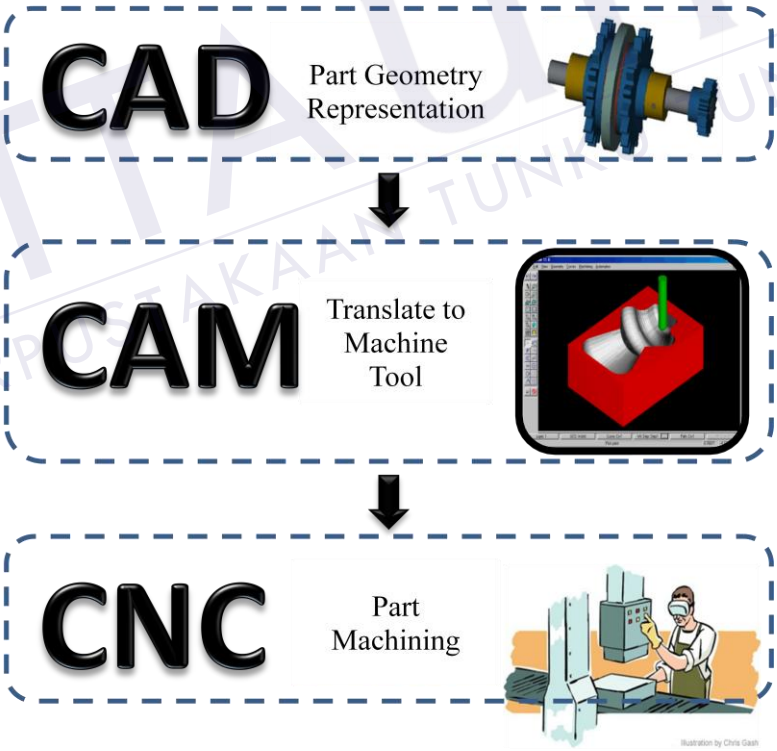

Figure 2.1: Manufacturing flow

2.3 G & M code weakness.

Manufacturing in its definition is “made by hand” (Kalpakjian et al., 2006). Inside a room, many things can be found which all of them manufactured by human. In real manufacturing industry, many components used to create products are made individually. An example is a printer where each component that builds a printer may be produced by different department or even different factory. All parts that are used to build one product will undergo basic manufacturing flow. It starts from consumer demand, designing, selecting raw material, production batch, inspection, warehouse and shipping to market. The manufacturing process will take a long way and time but in real world, manufacturing become rapid and productivity is one of important factor to ensure products will reach the market in the shortest time as possible. Looking back to the older times, manufacturing started since the primitive era where human survive their everyday life by carving tools and equipments by using their hand. They invent things to ease their everyday lifework. They use raw material such as wood, stone, gold, bronze and suitable material they can get. They carved stone, chiseled wood, and made pottery to create new things. A person instinctively knows how to create and innovate things to support their daily life. From time to time people start creating something that more advanced, sophisticated and ease their work by using high technology that are available in line with the manufacturing era. People start to know how to use technology where they come out with simple machine with mechanical features such as gear, level, handle and dial. Equipment such as spinning wheel, waterwheel, tackle and windmill help people decrease on the work force used while more output can be obtained.

When Industrial revolutions start in 18^{th} to 19^{th} century (Smid, 2003), it has a major impact on manufacturing, agriculture, transportation and culture of the society. It has changed the way people work and recognized as a major development for world history. They started producing products in enormous batch and selling their products all over the world. Transportation has become more agile and mobile. Horses and boats were not the main transportation, but it has been replaced by steam car and train. Textile industry has improved when spinning wheel is not used anymore but has been substituted with a machine that can produce a lot more products. All manufacturing process becomes more rapid and productive.

Numerical Control (NC) technology arrives when John Parson (1949-1955) (Smid, 2003; Olexa, 2001) at Massachusetts Institute of Technology (MIT) USA succeeded inventing rotor blade for helicopter where IBM computer was used and after few years later in 1955 NC is available in manufacturing industries. NC used a fixed logical function built in and permanently wired within the control unit. The function cannot be changed by machine operator thus its call as hardwired control. NC is an office environment where all changes are done away from the controller. In early NC system, punch tape was used as input for the programmed (Smid, 2003), CNC then arrived where it is called soft wired control (Smid, 2003) which used an internal microprocessor (a computer) but correction was still done away from the controller. There are various types of CNC machines that will do various task. Example of CNC machines that are currently available are mill and machining centers, lathes and turning centre, drilling machines, boring mill and profilers, Electrical Discharge Machining (EDM) machines, punch press and shears, flame cutting machines, routers, water jet and laser profilers, cylindrical grinders, and welding machines (Smid, 2003). As many of CNC machine type, plenty of machining work can be done repetitively without any concern to human weaknesses. The benefits (Smid, 2003) of using CNC machine are as the following list:

i. Setup time reduction
ii. Lead time reduction
iii. Accurately and repetitively
iv. Contouring of complex shape
v. Simplified tooling and work holding
vi. Consistent cutting time
vii. General productivity increase

Today manufacturing is far more advance and the competitiveness among manufacturer are very challenging. Without suitable technology, manufacturing process from design to production will be delayed and it cannot arrive in the market in the time demand. The intense of competition among manufacturers to deliver product into market in the earliest time made manufacturing environment face the rapid changes. The shifting involved many issues and the ultimate result is to achieve the highest technology, practicality in every production method and data

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